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UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
WASHINGTON, D. C.
H. H. BENNETT, CHIEF



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# RUN-OFF FROM SMALL DRAINAGE BASINS

by

D. B. Krimgold
Section of Watershed and Hydrologic Studies

SCS-TP-17
June - 1938

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## SYNOPSIS

This paper consists of a discussion of the need for run-off data from small drainage basins, an outline of the present status of the run-off problem, and a description of the run-off studies conducted by the Soil Conservation Service.

## THE NEED FOR RUN-OFF DATA

There is probably no problem in engineering that is more baffling than the determination of rates and amounts of run-off and of the frequency of their occurrence. Along with other hydrologic phenomena, rates and amounts of run-off must be considered in the rational and economic design of a multitude of engineering undertakings, large and small.

Quantitative data on these phenomena and on their interrelation are needed in determining maximum and minimum stages in

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*Watershed and Hydrologic Studies, Soil Conservation Service, In Charge, Run-off Studies on Demonstration Projects.

streams; maximum, average, and minimum yields of drainage basins; rates and amounts of run-off and stream flow; feasibility of storage and conveyance of water, etc., all of which are the basis for the design of various hydraulic works, including soil and water conservation structures.

Modern scientific methods of investigation of natural phenomena presuppose that some definite laws governing such phenomena exist. Investigations, experimentation, and observations are planned and directed with a view to discovering what these laws are.

Hydrologic phenomena in general and run-off in particular are extremely complex. The factors affecting run-off are numerous and only few of them are constant. It is obvious that in attempting to arrive at the laws governing such complex phenomena, the inductive method of reasoning must be employed. This method involves the formulation of a hypothesis and its verification by the study and examination of many individual instances.

Many hypotheses based on pure rationalizations were found to be erroneous and were abandoned in the light of results from carefully conducted experiments and measurements. The "Parabolic theory" of Guglielmini is an interesting example:

> Toward the end of the 17th century, Guglielmini (1658-1710), who was known as the greatest master of the Italian School of Hydraulics, developed the parabolic theory of flow in streams and published a book entitled "La Misura

> Dell'acque Correnti" (1).* According to this theory, the velocity of water in a river must be greatest at the bottom and zero at the surface. (We know now that the contrary is more nearly the case). By actual measurements with the tube bearing his name, Pitot was able to demonstrate the fallacy of the parabolic theory advanced by Guglielmini. It was not until Pitot presented his results before the Paris Academy of Sciences in a treatise prepared by him in 1732 that the parabolic theory was discarded.

The study of run-off phenomena is probably still in the pre-hypothesis stage. The important basic factors entering into the problem are only now being fully recognized and defined.

The rapid developments of industry, agriculture, and transportation, and the creation of large centers of population called for the immediate undertaking of large projects, the planning and design of which must be based on adequate knowledge of the laws governing run-off, or for the lack of such knowledge, on specific information applicable to individual cases.

It was obviously impractical to wait with the planning of such projects and the construction of great hydraulic works until the laws governing run-off and other hydrologic phenomena were established. The second alternative was therefore resorted to. To meet these immediate needs, run-off and other hydrologic data have been collected throughout the world for the past 100 years or longer with a view to solving more or less specific local problems.

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*Numbers after names of authors and articles refer to the list of references given at the end of this paper.

Notwithstanding the large amount of stream-flow data secured through the work of the United States Geological Survey and similar agencies throughout the world, it is generally conceded that the existing information on run-off is insufficient for the rational planning and design of hydraulic projects. This is especially true with regard to projects and structures involving run-off from small drainage basins.

In attempting to secure run-off data, priority was naturally given to the type of data required in connection with projects of outstanding economic and social importance, such as domestic, irrigation, and industrial water supply, hydroelectric power, navigation, and flood-control projects. It is for this reason that with but few exceptions, the gaging stations of the U. S. Geological Survey were established on the major rivers and on their larger tributaries. The need for run-off data from small rural and urbanized areas has long been recognized in connection with the construction and maintenance of highways, railroads, and storm sewers. This need has recently become most urgent in connection with the soil and water conservation work conducted by various State and Federal agencies. It will become even more acute in the United States when the Department of Agriculture fully assumes the responsibility placed upon it by Congress in the "Omnibus Flood Control" and "Water Facilities" acts, and when it begins to discharge its obligations to the Soil Conservation

Districts as described by D. S. Myer in "Soil Conservation Districts" (2). In fulfilling these obligations, adequate information for the design of thousands of smaller hydraulic structures will be required. The aggregate cost of these structures will run into millions of dollars. The construction of such structures without adequate information often results in either underdesign entailing costly failures or in overdesign. In case of smaller structures, the consequences of overdesign are even more serious than those of underdesign, since good practices are often discarded as uneconomical because they are grossly overdesigned.

## THE PRESENT STATUS OF THE RUN-OFF PROBLEM

In order to meet the urgent immediate need for design data, many attempts were made to develop methods and formulae for estimating run-off from drainage basins on which no records were collected.

A large number of empirical run-off formulae have been developed by engineers in the United States and elsewhere. In "Formulae and Methods in General Use by Engineers to Determine Runoff from Watershed Areas" (3), T. A. Munson lists 36 formulae and four sets of curves that are in standard use in the determination of run-off and sizes of drainage structures. He classifies them under four general headings, namely:

A. RUN-OFF FORMULAE FOR METROPOLITAN DISTRICTS AND STREAMS.

(7 formulae, including Kuichling's Q = CIA)

B. RUN-OFF FROM SMALL AREAS, SWAMPS, AND WET LANDS.

(6 formulae)

C. FLOOD FLOWS FROM WATERSHEDS OVER 200 SQUARE MILES IN AREAS.

(13 formulae and 2 sets of curves)

D. FORMULAE AND CURVES TO DETERMINE BRIDGE AND CULVERT SIZES.

(10 formulae and 2 sets of curves)

(Munson's list is by no means complete. Many curves and formulae, including the Ramser curves used extensively in the design of erosion-control structures, were not listed.)

The various methods of estimating floods are discussed in Water Supply Paper No. 771 (4) of the U. S. Geological Survey under the following headings:

"A. EXTREME-FLOOD FORMULAS.

B. FLOOD-FREQUENCY FORMULAS.

1. Formulas with frequency relation implied.
   a. Formulas involving only drainage area.
   b. Formulas involving length or width of drainage basin.
   c. Formulas involving rainfall plus other factors.
   d. Formulas involving total flood run-off.
2. Formulas with frequency relation expressed.

C. STATISTICAL (OR PROBABILITY) METHODS.

1. Theoretical probability curves.
2. The duration-curve method.

D. METHODS DEPENDENT ON RELATION OF RAINFALL TO RUNOFF.

1. "Rational" methods.
2. The unit-hydrograph method.

E. METHOD FOR ESTIMATING PEAK FLOW FROM 24-HOUR AVERAGE FLOW."

An examination of the various formulae and methods reveals that many of them were developed for specific localities and some are further limited with respect to the size of the drainage basins to which they apply. Still others are applicable to run-off and floods of certain frequencies. It is interesting to note that the formulae listed by Munson under "B" and "D" and all but two under "C" contain only one variable, namely, the size of the drainage area in square miles or in acres. All of the formulae listed under "A", except the Kuichling formula (Q = CIA), contain the average slope and the maximum intensity of rainfall in inches per hour in addition to the size of the drainage area.

It appears that in developing the various formulae referred to above, the paramount objective was to find some simple device which will give the answer to the troublesome problem and will involve the determination of the simplest factors, such as the area of the drainage basin. All serious students of the run-off problem, including most of the men who are responsible for these formulae, fully realize that they do not truly depict the relationships between the most important factors affecting run-off.

The so-called "rational formula", Q = CIA, deserves particular mention. It has come into more or less general use in connection with the design of sewers, erosion-control structures,

highway culverts, and other hydraulic structures on comparatively small drainage areas.

On the face of it, this formula is probably less expressive of the factors affecting run-off than some of the others which involve the average slope in addition to the rate of precipitation and size of drainage area. However, this formula, or rather, the rational method which it is supposed to express, is probably responsible for a great deal of the recent advance made towards the discovery of the important factors affecting run-off. The discussion of the rational method in Water Supply Paper No. 771 (4) contains the following statement:

> "The formula used in connection with this method is one of the most convenient yet devised for showing the relation of rainfall to maximum expected run-off from areas within the range of its proper use, as follows:
>
> $$Q = C\ i\ A$$
>
> where $Q$ = maximum run-off, in c.f.s.
> $C$ = the percentage of average rainfall appearing as run-off at the end of the prescribed period at the point of observation.
> $i$ = average rainfall intensity prevailing during the period, in inches per hour.
> $A$ = drainage area in acres.
>
> This formula is simplified by the coincidence that 1 acre-inch is very closely equivalent to 1 c.f.s. for 1 hour."

C. E. Ramser in "Run-off from Small Agricultural Areas" (5) describes the rational method as follows:

> "In the rational method of computing run-off the various factors influencing run-off are provided for in the formula Q = CIA. C, the coefficient of run-off, is the composite effect of all factors influencing run-off which have been mentioned. I, the rate of rainfall to be provided for, depends upon the intensity for different durations of rainfall for the particular locality, and the duration to be used for any particular watershed is equal to the time of concentration of that watershed. Thus the time of concentration takes care of such influencing factors as the shape and slopes of the watershed and the arrangement and character of the drainage channels. To a certain extent, also, it takes account of the vegetation on the watershed, since the distance traveled and the velocity of the water depend partly upon these factors."

In a preceding paragraph of the same article entitled "Some factors influencing the rainfall and run-off relation", he discusses the "apparently unaccountable variations in the runoff coefficients" obtained by him for the various watersheds on the Murchison farm, and states that "there are many interdependent factors entering into the relation between rainfall and runoff, and it is practically impossible to evaluate all of them accurately." He mentions "the effect of previous rains upon the capacity of the ground to absorb water from subsequent rains" and lists a number of factors to be considered. Ramser's discussion of the factors affecting run-off is most valuable because it is based on actual observations.

The run-off data collected by him in 1918 on the Murchison farm and their publication in 1927 were undoubtedly one of the most important contributions toward the discovery of many factors

which had not been previously recognized. Since the publication of these data, a limited amount of information on run-off from small drainage areas was collected on the several Erosion Experiment Stations (6-10) of the Soil Conservation Service. This information is being published and will undoubtedly be fully utilized in the near future. An 11-year record of run-off and rainfall from the Ralston Creek Watershed was recently published by the University of Iowa (11). The run-off and precipitation data from the Wagon Wheel Gap (12), the Great Basin (13), and from other studies on small drainage basins in the United States and abroad have not yet been fully utilized in the design of hydraulic structures on small drainage basins.

Although the various studies conducted thus far were more or less fragmentary, they were sufficient to set the students of run-off phenomena on the right track toward the discovery of the factors affecting run-off. In their book on American sewerage practices (second edition), Metcalf and Eddy (14) devote considerable space to the discussion of the rational method, which they consider the best available for the determination of run-off in connection with the design of storm sewers. They consider the coefficient of run-off C to be a composite of four factors which may be called: the coefficients of imperviousness; of distribution of rainfall; of retention; and of retardation. The time of concentration entering into the determination of the rate of rainfall in

the rational formula is defined in this book as the "period of time required to establish runoff and for the water to flow from the most distant point (measured in time) to the point under consideration."

These discussions of the "runoff coefficient" and the definition of the "time of concentration" show rather clearly how complex and indeterminate the so-called rational method really is.

M. M. Bernard (15) lists 18 of the most important factors "entering into the analysis of flood flow on any particular watershed." He classifies 6 of them as permanent and 12 as variable.

It appears from the foregoing discussion that although the rational method was instrumental in bringing about a clearer understanding of the factors entering into the problem of determining run-off, it is far from being the solution of this problem. In the hands of unqualified users, the rational method becomes a rather dangerous and misleading device.

The evaluation of the numerous factors which must be considered in arriving at the proper run-off coefficient, time of concentration and rate of rainfall is so involved that only the best qualified hydrologists can and should venture to estimate them. The only determinate factor in the rational formula is the drainage area in acres which can be readily measured.

One of the great shortcomings of the rational formula is that it is generally assumed that the maximum run-off will occur

when the maximum average precipitation rate for the selected interval of time takes place. In other words, the ordinary user of this formula assumes that the frequency of precipitation is also the frequency of run-off, which is, of course, not necessarily true. The subject of frequency of run-off from small drainage basins is important enough in the design of hydraulic structures to be treated in a separate paper and will not be further discussed at this time.

E. P. Arneson's "Rational Runoff Theory Applied to the Design of Road Ditches and Channel Changes" (16) is one of the most interesting discussions of the rational method. He points out the difficulty of estimating "the time required for storm water to flow over the surface of the ground to its entry into a channel", and states that "this time is often the larger part of the entire time of concentration for the watershed." It would seem that in view of the many uncertainties, the safest way to use this method would be in accordance with the following procedure suggested by C. E. Ramser (5) in "Run-off from Small Agricultural Areas":

> "In determining the probable rate of run-off from any particular watershed the rational method should be employed. Values of C, I, and A should be determined for substitution in the equation Q = CIA. A, the watershed in acres, should be determined from a map if available, or from a survey of the watershed. C, the run-off coefficient, should be selected from the experimental values for C given in Tables 2 to 7, such revisions being made as seem necessary to

account for differences in characteristics.* I, the rate of rainfall in cubic feet per second per acre--for practical purposes this is the rate of rainfall in inches per hour--depends upon the time of concentration for the watershed, and upon the frequency period decided upon. The time of concentration can be determined approximately by measuring the distance and estimating the average velocity from the most remote point to the outlet of the watershed, by channel."

In view of the uncertainties involved in the determination of the "time of concentration", the above procedure would be even safer and more adequate if it specified that the time of concentration be determined in the same manner as the "runoff coefficient."

As more data on run-off from watersheds of various characteristics become available, the task of estimating run-off will become increasingly simplified. At the same time, the increased amount of information will form the basis for a more satisfactory solution of the run-off problem. Already a noteworthy attempt has been made to enumerate the basic factors which must be known in order to solve the run-off problem and through it many other hydrologic phenomena. In a paper on "Hydrologic Interrelations of Water and Soils", R. E. Horton (17) refers to the Infiltration theory of surface runoff. Under "Relation of Surface Runoff Phenomena to the Controlling Variables" he states:

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* Underscored by D.B.K.

"Considering direct surface runoff alone, as distinguished from the channel phase of runoff, and excluding ground-water flow, it is evident from the preceding that all the phenomena of surface runoff are governed by the following independent variables:

1. Rain intensity and its distribution.
2. The duration of different phases of the rain intensity graph.
3. Infiltration capacity (f)
4. Depression storage ($V_d$)
5. Surface slope (S)
6. Length of overland flow ($l_o$)
7. Roughness of the surface (n)
8. Character of overland flow, whether turbulent, mixed, laminar, or subdivided by grass, etc. This governs the value of the exponent M in the overland flow equation."

It is too early to say whether the infiltration theory of surface run-off will give the answer to the run-off problem, and, if so, whether it will afford a means for the solution of specific practical problems. With a few assumptions, which he himself feels should be verified by factual data, Horton was able to offer what is, in effect, a reasonable hypothesis. Whether it will stand the test of verification by carefully planned experiments and observations, is yet to be proved.

He was, however, able to arrive at the several basic independent variables and to suggest the functional relationship between these variables. It will still be necessary to determine the numerical coefficients to make this functional relationship useful in the solution of practical problems. These coefficients, however, are numerical values which are not themselves functions

of a large number of variables as are the so-called "coefficient" of run-off in the rational formula or the "time of concentration."

In order that Horton's infiltration theory may be adequately tested and the necessary numerical coefficients obtained, it is necessary to secure a large number of run-off hydrographs and records of rainfall such as are obtainable from run-off and precipitation measuring stations equipped with suitable recording instruments. Together with these records, accurate information on the characteristics of the watersheds must also be secured. But isn't this also the type of information required to meet the immediate needs for run-off data needed in connection with the extensive program of soil and water conservation, flood control, and water utilization?

## RUN-OFF STUDIES CONDUCTED BY THE SOIL CONSERVATION SERVICE

Adequate data on run-off from small drainage areas are indispensable in the development and application of adequate methods for soil and water conservation, proper water utilization and the control of floods on upstream tributaries of larger rivers. This was fully recognized by the Soil Conservation Service from the very inception of its work. The engineers of the Service were faced with the task of designing terraces, channels, check dams, impounding dams, spillways and other hydraulic structures throughout the United States. Except for the limited data from

the Murchison farm studies and the Ramser curves (18) which were based largely on these data, there was practically nothing to go by in designing such structures. The Service as a whole was also in need of quantitative data on the effects of soil and water conservation practices on run-off, erosion, and floods.

It was in order to secure this information that the Section of Watershed and Hydrologic Studies of the Division of Research was established soon after the Soil Conservation Service was made a permanent agency by Act of Congress in April 1935.

In November 1935, the general working plan for Experimental Watershed Studies (19) was prepared by the Section of Watershed and Hydrologic Studies on the North Appalachian Experimental Watershed. The objectives of the studies were stated as follows:

"(A) To determine the effect of land use and erosion control practices upon the conservation of water for crops and water supply and upon the control of floods under conditions prevailing in the North Appalachian Region of the United States.

(B) To determine the effect under (A) for small and large areas and to trace variations in this effect from the smallest plot and lysimeters through a series of intermediate watersheds to the largest watershed on the project.

(C) To determine the rates and amounts of runoff for precipitation of different amounts and intensities for watersheds typical of the North Appalachian Region of different configuration, size, shape, topography, cover, underground conditions, land use and erosion control practices. To furnish data needed for use in the design of erosion control structures and in

> the design and operation of the Muskingum Watershed Conservancy District and other flood control projects lying within the North Appalachian Region."

It should be noted that one of the major objectives of the experimental watersheds was to secure run-off data needed in the design of hydraulic structures.

The studies on these experimental watersheds are to continue for a long period of time in order that the effects of land use and soil and water conservation practices can be properly determined. The work, however, was originally planned so that run-off data for use in design would become available in the early stages of the studies.

The establishment of the North Appalachian and the Texas Experimental Watersheds is practically completed and records from them are being obtained. The establishment of the Great Plains Watershed near Hastings, Nebr., has recently begun. Several papers describing the various phases of the work on these Experimental Watersheds were published in "Agricultural Engineering", "Soil Conservation", and in other technical journals. Ramser's article (20) in the February 1938 issue of "Soil Conservation" contains a complete description of the experimental watershed studies.

By the fall of 1936, it became apparent that in order to secure the urgently needed run-off data for the various parts of the country, run-off studies on the various demonstration

projects scattered throughout the United States would have to be resorted to in addition to the experimental watershed studies. This, together with an urgent request for information by the Engineering Section of the Service, resulted in the inauguration of the run-off studies on 21 projects in the 11 regions of the Soil Conservation Service by the Divisions of Operations and Research of the Service.

The procedure followed in the selection and establishment of these studies; the instrumentation and methods used to secure the data; the proposed method of compilation and dissemination of the data; and the organization and present status of the work are briefly described in the concluding part of this paper.

Selection of Sites and Establishment of Studies.

The type of run-off data needed in the various regions of the Service in connection with the design of soil and water conservation structures and practices are determined jointly by a representative of the Section of Watershed and Hydrologic Studies and the regional technicians (engineers, soil scientists, and agronomists).

After the type of run-off data most urgently needed in the "Runoff problem areas" in a given region is determined, the projects that are most representative of the run-off problem areas are designated for such studies. From three to six typical drainage areas are selected on each of these projects. Preliminary

topographic soil and cover maps of the selected areas, as well as plans, profiles, and cross-sections of the proposed sites for the run-off measuring stations, together with a complete description of the areas and of the cropping plans, are prepared. With this information, the necessary approvals are secured and the run-off and precipitation measuring stations are designed by the Section of Watershed and Hydrologic Studies of the Division of Research. The facilities and personnel of the project are utilized in constructing the installations and in making the necessary surveys and observations.

Instrumentation and Methods Used in Securing the Data.

In order to attain the objective of the run-off studies, the information secured must include (1) adequate run-off hydrographs; (2) complete records of amounts, rates, distribution, and time of occurrence of precipitation; (3) accurate information on the permanent characteristics of the drainage basins; and (4) sufficient data on the conditions of the soil and vegetative cover at the time run-off occurs.

A set of detailed instructions and outlines of procedure covering all the phases of the work are now being prepared. Little or no precedent exists for many phases of the work. The various instructions and outlines of procedure are undergoing constant revision in the light of the experience gained during the construction period and during the first season of operation. Many

improvements in the instrumentation have been made since the earlier run-off studies were undertaken, yet a great deal still remains to be done. The same is true with respect to methods of compilation and analyses of the data. No attempt will, therefore, be made to give more than a very brief and general description of the instrumentation and methods to be used in these studies.

Run-off Hydrographs.--The storm run-off from small drainage basins is of very short duration. The fluctuations in stage are very rapid and the critical peak flows persist for only a few minutes. It is extremely difficult and often impossible to secure adequate run-off hydrographs from such drainage basins by means of current meter measurements.

Some automatic run-off measuring device must therefore be used. Such a device to be suitable for the various conditions encountered must meet the following requirements:

(a) It must have a definite, continuous, and stable stage-discharge relationship for both rising and falling stages which can be established without recourse to current meter measurements.

(b) It must fit the topography of the selected site as closely as possible so as to create a minimum of temporary pondage and a negligible volume of permanent pondage.

(c) It must be possible of rating in a hydraulic laboratory.

(d) Its rating must not be seriously affected by submergence.

(e) It must not seriously interfere with farming operations.

(f) It must be self-cleaning.

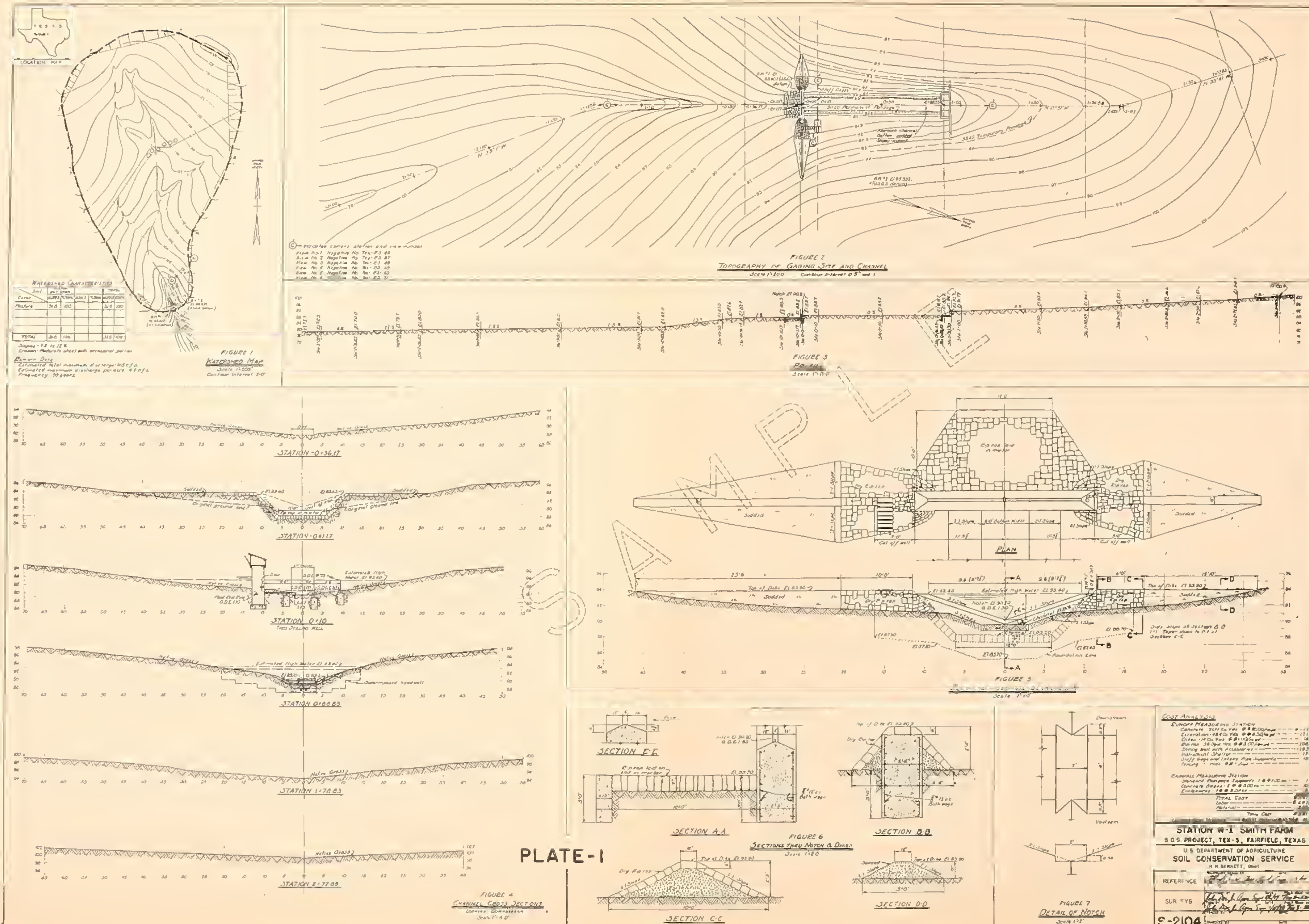
(g) It must be durable and simple to construct.

(h) The tolerance in its dimensions and form must not be too narrow.

(i) It must be inexpensive to build and to maintain.

(j) The measuring station, together with all of its appurtenances, must occupy as little space as possible.

After considering all available measuring devices, including weirs and flumes, it was found that a triangular, broad-crested weir would be most suitable to meet the above requirements. Preliminary investigations were conducted at the National Hydraulic Laboratory on small scale models in order to develop the simplest possible weir crest suitable for the purpose. These investigations resulted in the crest shown in figure 6 of Plate 1. Triangular weirs with this crest and side slopes of 2 (horizontal) to 1 (vertical), 3 to 1 and 5 to 1 are employed. Plate 1 represents a sample drawing of a completed weir with 3:1 side slopes. The small scale tests indicate that such weirs will satisfactorily meet the requirements outlined above and will function properly under a wide range of field conditions. Calibration curves for the weirs thus far constructed are now being developed at the Cornell University Hydraulic Laboratory through tests of large scale models and full



LOCATION MAP
TEXAS
WATERSHED CHARACTERISTICS
Pasture
TOTAL
FIGURE 1
WATERSHED MAP
Contour Interval 2.0'
FIGURE 2
TOPOGRAPHY OF GAGING SITE AND CHANNEL
FIGURE 3
PROFILE
STATION -0+36.17
Native Grass
STATION 0+01.17
Sodded
Original ground line
STATION 0+10
STATION 0+66.83
Estimated high water
STATION 1+78.83
Native Grass
STATION 2+78.83
FIGURE 4
CHANNEL CROSS SECTIONS
PLATE-I
PLAN
Sodded
Dry Rubble
Cut off wall
FIGURE 5
Foundation Line
SECTION E-E
SECTION A-A
FIGURE 6
SECTIONS THRU NOTCH & DIKES
SECTION B-B
SECTION C-C
SECTION D-D
Downstream
Upstream
FIGURE 7
DETAIL OF NOTCH
COST ANALYSIS
RUNOFF MEASURING STATION
Shelter well with Accessories
Instrument Shelter
RAINFALL MEASURING STATION
TOTAL COST
Labor
Material
STATION W-1 SMITH FARM
S.C.S. PROJECT, TEX-3, FAIRFIELD, TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT, Chief
REFERENCE
SURVEYS
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size structures under simulated field conditions. Tests are also being made with a view to reducing the width of the crest from 30" to 16". The cost of future weirs will be reduced materially if the results of these tests prove satisfactory.

The head over the weirs is measured by means of water level recorders capable of recording unlimited range in stage on a scale of 5" of chart = 1 foot of stage. Weekly, daily, 12-hour and 6-hour time scales are obtainable by changing gears and pinions of the 8-day recorder clock. The 6-hour chart gives a time scale of 1" = 25 minutes. This time scale is being used on practically all of the installations. The water level recorder is housed in an instrument shelter surmounting a stilling well which consists of a currugated culvert. A float rest ring, a ladder, one or more intake pipes, equipped in some cases with a valve and flush tank constitute the appurtenances of the stilling well. The intake pipes are placed 10' upstream from the center of the 4" surface of the weir crest. Outside staff gages are used to check the elevation of the water in the stilling well. Figures 1, 2, 3, and 4 show the various stages of construction of one of the weirs. Views of completed installations are shown in figures 5, 6, 7, and 8.

The recording pen actuated by the float traverses a line on the chart mounted on the vertical clock cylinder. This line represents the change in head over the weir with respect to time. With calibration curves (corrected for storage) available for every

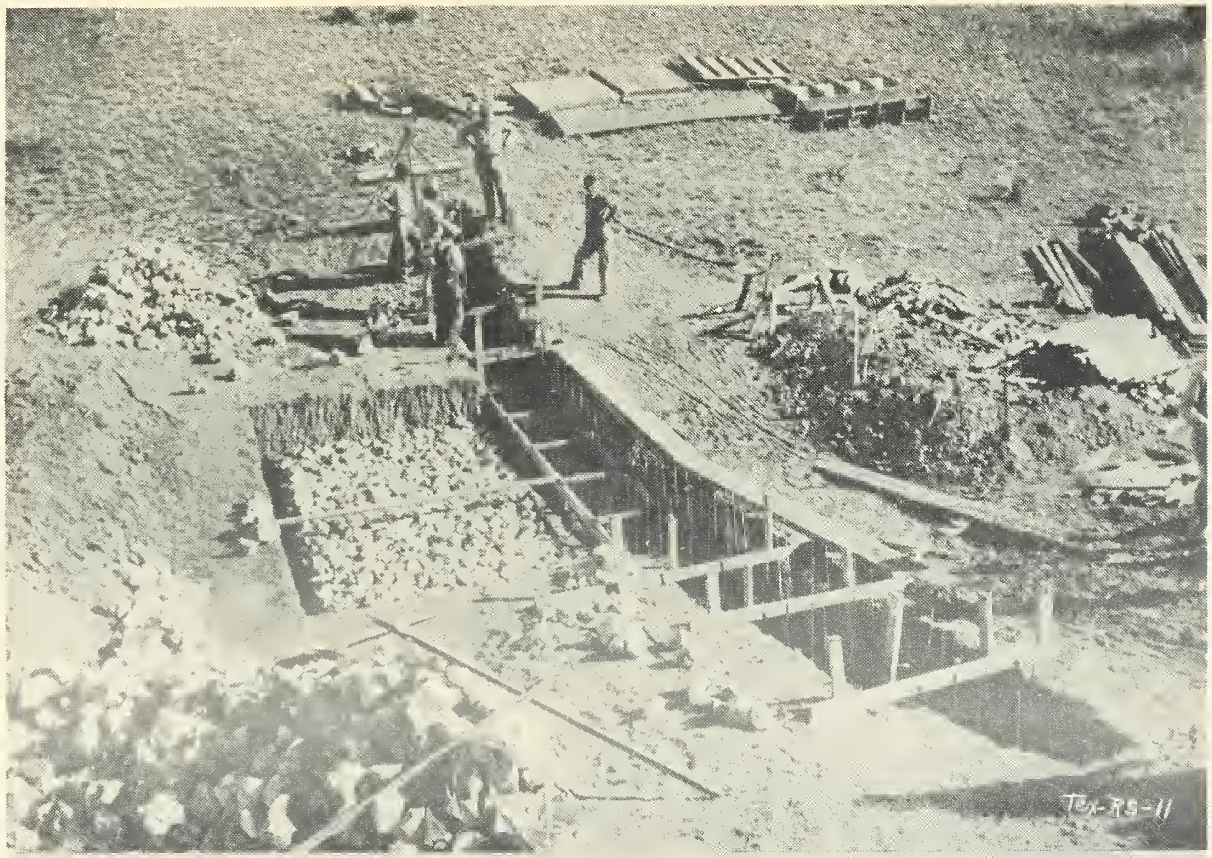



Figure 1.—A 5:1 triangular weir with trapezoidal crest in the early stage of construction on the Vega, Texas Project of the Soil Conservation Service. This weir was built on a 143-acre drainage basin and has a capacity of about 590 c.f.s.

Figure 2.-Placing temperature reinforcement in the weir shown in figure 1.


Figure 3.-Completing the placing of concrete in the lower portion of the weir just before the crest forms are placed on the weir shown in figure 1. Note the heavy bracing of the forms used to insure proper slope.

Figure 4.-Top crest forms in place and the pouring of the weir shown in Figure 1 practically completed.

Figure 5.-View of the completed weir shown in figure 1, looking upstream. Note the concrete apron and the partially completed downstream channel.

Figure 6.-Same as figure 5, but looking downstream. Note the wide channel of approach, the height of the notch above ground, the staff gages, the stilling well, and the intake pipes.

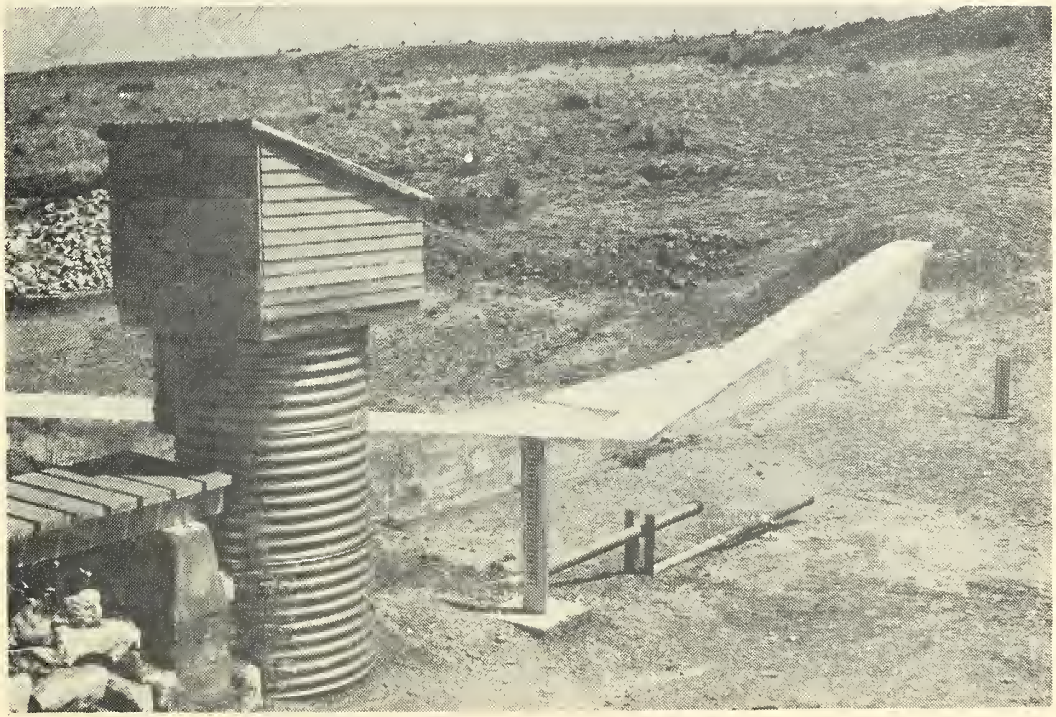


Figure 7.-Close-up of stilling well and appurtenances at the weir shown in figure 5.

Figure 8.–Close-up of stilling well and appurtenances at weir shown in figure 5, showing the installation of the flush tank.

weir, the stage as indicated by the recorder chart is converted into discharge and the Run-off Hydrograph for a given storm is plotted.

Precipitation Records.--One or more rainfall measuring stations are established in each drainage basin. Each station consists of a recording rain gage of the Fergusson type and a U. S. Weather Bureau Standard gage, the latter being used to check the total catch and the operation of the recording gage mechanism. The stations are located so as not to interfere with farming operations, and are exposed as nearly as possible in accordance with the recommendations of the Subcommittee on Standards of the National Resources Committee. Two types of Fergusson rain gages are used, one with a recording capacity of 6" and a chart scale of 1-1/2" = 1" of rainfall, and the other with a recording capacity of 9" and a chart scale of 1" = 1" of rainfall. Both types are equipped with 8-day clocks and either weekly, daily, 12-hour or 6-hour charts.

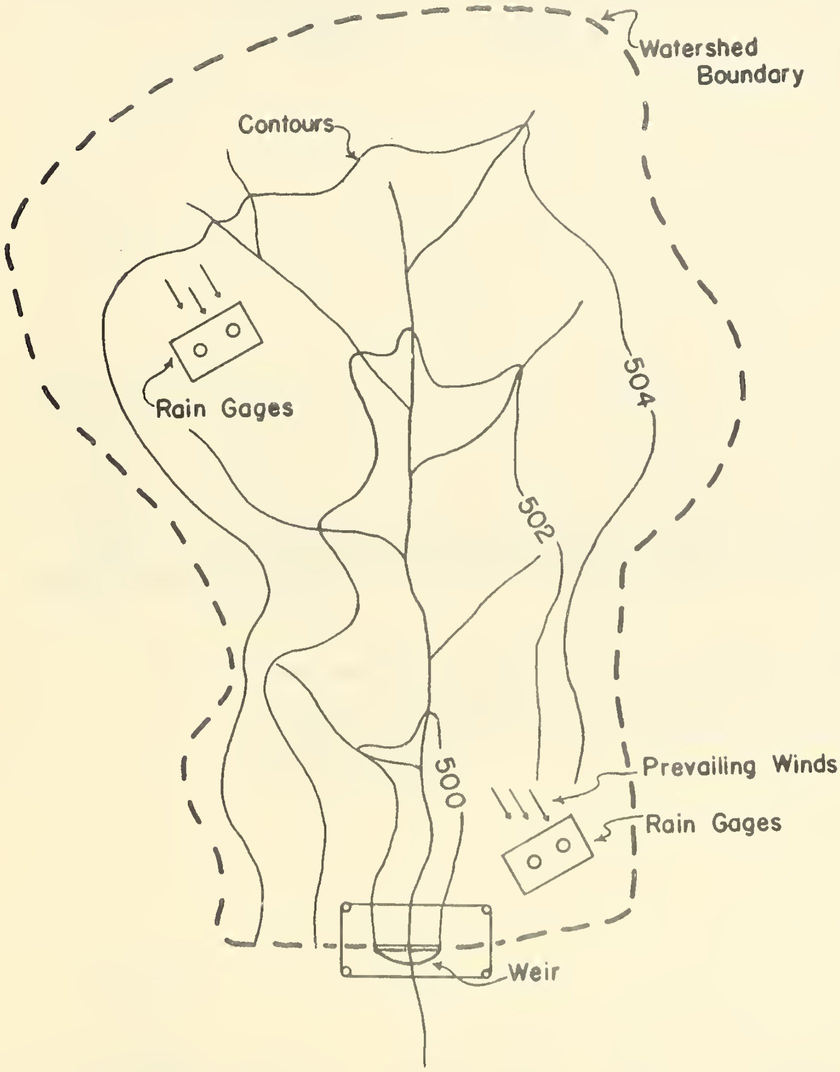
The 12-hour charts giving a time scale of about 1" = 1 hour is employed on all rainfall measuring stations. Other scales may be used if experience gained in the course of the first season should indicate the advisability of doing so. The record on the chart represents a mass curve of the total rainfall collected in the gage. The slope of the tangent at any point on this curve represents the intensity of rainfall in inches per hour. This curve

also shows the time of beginning and end of rainfall and its distribution with respect to time. Standard drawings of rainfall measuring stations are shown in plates 2, 3 and 4. Views of completed installations are shown in figures 9 and 10.

Where the precipitation occurs in the form of snow, it is necessary to determine the amount of snow accumulated on the drainage area and its water equivalent. On large drainage basins, snow courses are employed for this purpose. A simpler and more accurate method is being developed for these run-off studies. It involves the use of a sufficient number of "snow scales", consisting of graduated stakes properly distributed over the drainage basin. Readings of depth of snow are obtained from the "snow scales" by means of a transit or a pair of binoculars and are plotted on a map. The water equivalent is determined by means of samples taken at a number of carefully selected locations.

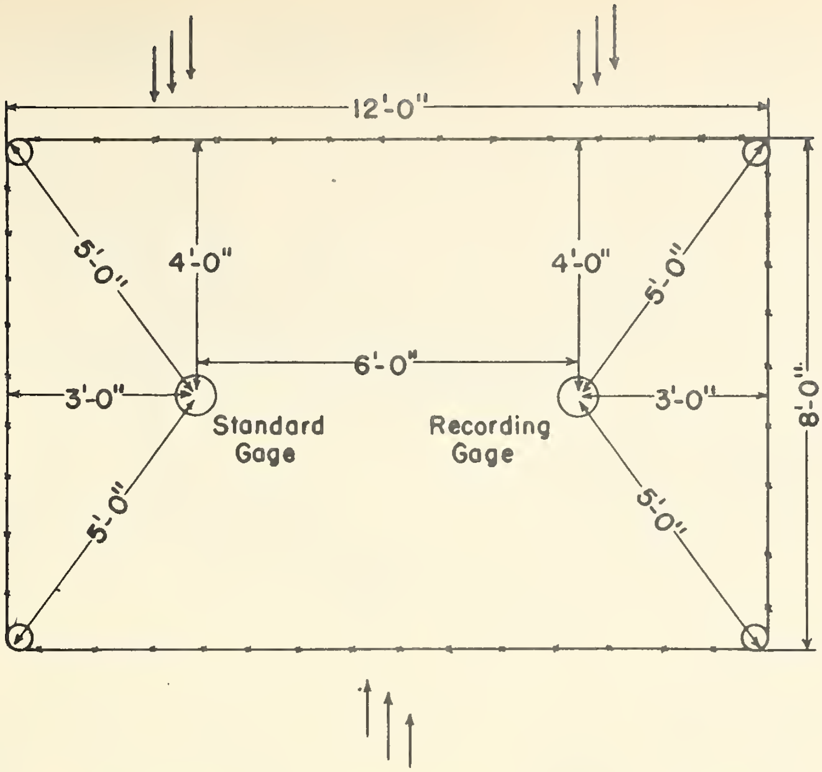
The total amount of snow and its water equivalent for the various portions of the drainage basin are determined from the map and the samples. The number of such determinations during the winter season will vary with prevailing conditions. One or two may suffice for northern Montana, while more frequent determinations may be required in the Pacific Northwest, due to the warm Chinook winds.

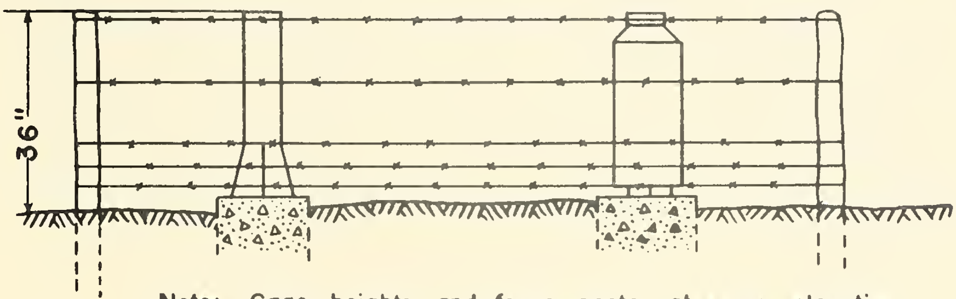
The rainfall and run-off measuring stations are inspected, the clocks are wound and the charts changed once a week during dry



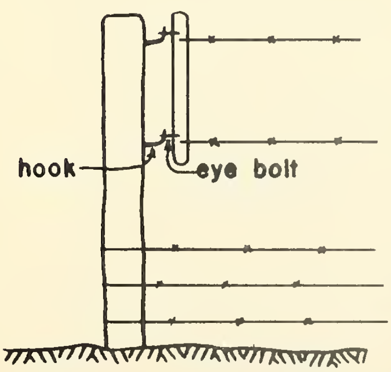

TYPICAL INSTALLATION OF RAINFALL MEASURING STATIONS ON DRAINAGE BASINS OF 30 TO 200 ACRES

PLATE 2




Note: Gage heights and fence posts at same elevation. In order to eliminate disturbing air currents, the posts should be set without bracing above ground.

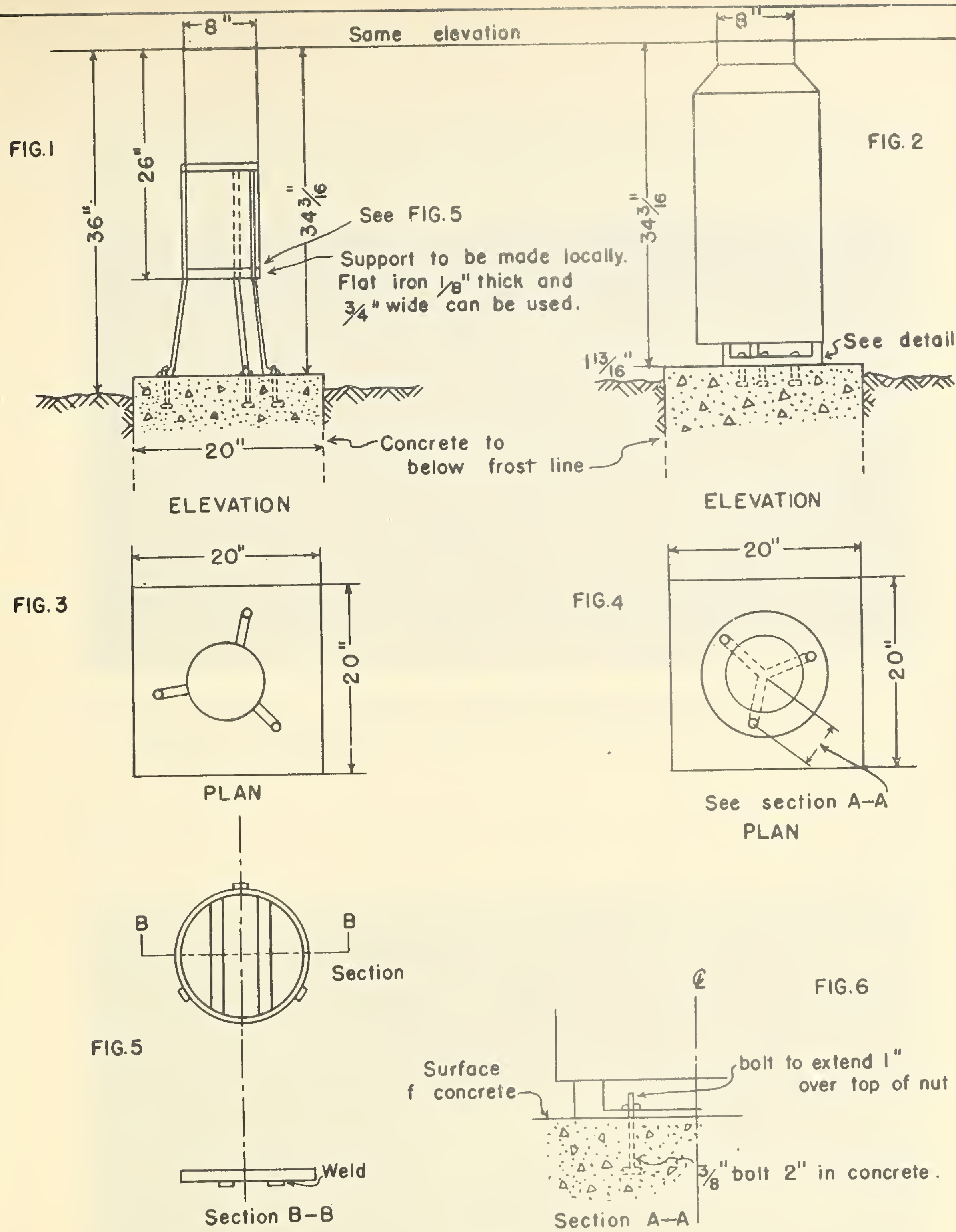



In order to provide easy access without constructing a gate, a suggested fastening for the top wires of one of the 8' sections is shown at the left.

If possible, iron posts set in concrete, with a 24" gate made of iron rod or small angle frame are recommended.

PLAN AND ELEVATION OF ENCLOSURE FOR RAINFALL MEASURING STATION

PLATE 3




DETAILS OF A TYPICAL RAINFALL MEASURING STATION

PLATE 4

Figure 9.-View of a rainfall measuring station on a 23.6-acre drainage basin on the Vega, Texas, Project of the Soil Conservation Service.

Figure 10.-General view of the 23.6-acre drainage basin shown in figure 9, with the rainfall measuring station in the foreground.

weather. The time indicated by the rain gage and water level recorder clocks is checked against a standard timepiece carried by the observer and recorded on the charts and in field books provided for this purpose. The necessary corrections are applied in compiling the data.

In addition to the weekly inspections, the stations are visited during and immediately after every rain. During these visits, the readings of the water level recorders are checked against the outside staff gages, and the readings of the recording rain gages are checked against the measured rainfall collected in the standard rain gages.

Permanent Characteristics of the Drainage Basins.--The permanent characteristics of the drainage basins and the conditions existing at the time run-off occurs must be known if the resulting data are to be useful in arriving at the laws governing run-off. This information is also required in order to apply the data to other locations within the Run-off Problem Area represented by each of the drainage basins under investigation.

The permanent characteristics of small drainage basins affecting run-off include:

(a) Length and degree of surface slope.

(b) Configuration of the surface.

(c) Drainage pattern and drainage density.

(d) Lengths, slopes, shape and cross-sectional areas of watercourses.

(e) Improvements, such as terraces, structures, buildings, fences, field boundaries, etc.

(f) Exposure or aspect of the various parts of the drainage basin.

(g) Depth, texture, and structure of the soil and subsoil.

(h) Permanent vegetal cover, such as wood lots and grasslands.

To secure the information on the above characteristics, detailed topographic maps on scales from 1" = 100 to 1" = 1000' are made, with contour intervals of 2' or larger, depending on the size and steepness of the areas. More detailed surveys are made of the temporary pond created by the measuring weirs during high flows in order that the discharge can be corrected for storage. The topographic maps of the temporary ponds are plotted on a scale of 1" = 20', with a contour interval of 0.5'. From such topographic maps, the information listed under (a) to (h) is readily obtainable.

Detail soil surveys giving the characteristics and depth of the topsoil, subsoil, and the parent material are made. The information is plotted on the topographic map. Longitudinal and traverse sections of the drainage basins are prepared to show the variation in depth of soil over the various parts of the watershed. The permanent vegetal cover is accurately determined and plotted on the topographic map.

<u>Conditions of the Drainage Basins</u>.--The variable conditions affecting run-off include:

1. The moisture content or degree of saturation of the soil and subsoil.

2. The temperature of the soil.

3. The tillage of the soil.

4. The type, density, and condition of crops or of grass and timber cover.

A careful record of rainfall and temperature conditions during periods preceding run-off will be kept on each of the projects. A set of Maxima and Minima thermometers and a hygrothermograph are included in the equipment for each project. Soil temperatures will be determined by means of thermocouples and soil thermographs. Soil moisture conditions will be determined by field examination and by means of simplified moisture determinations wherever possible. The condition of crops and other vegetal cover will be indicated on maps accompanying the record of every run-off period.

## Compilation and Dissemination of Data.

There has been considerable criticism of the common practice to withhold the publication of basic data until they are completely analyzed. It is true that some types of run-off data may be misleading if they are prematurely published without an adequate analysis. This is especially true in the case of data collected for the purpose of determining effects of various

practices. The data to be collected from the run-off studies, however, do not fall in this category. The need for the information is so urgent that it is imperative to disseminate it as soon as it becomes available without waiting until final analyses are made.

The data must be compiled in such a manner as to include all the pertinent records so that the information can be utilized by engineers in the design of hydraulic structures and by students of run-off phenomena in subjecting them to such study and analysis as they may be capable of making. There are many eminent hydrologists outside of the government service who are as qualified to make full use of such information, if not more so, than government employees. This is fully recognized by the Soil Conservation Service and by other government agencies, such as the Weather Bureau, the Geological Survey and others. The preliminary publication of the data collected on the Erosion Experiment Stations (6-10) prove the earnest attempt to make available as much of the data as possible without delay.

A method of compilation is being developed which will enable the distribution of the collected information at the end of every season of precipitation with a minimum expenditure of time and money. This method involves the preparation of data sheets for individual run-off periods on each of the watersheds under investigation. Such sheets will contain a full description of the permanent characteristics of the drainage basin and of the conditions of

the watershed at the time run-off occurs, the run-off hydrograph, the mass curve of current precipitation and a record of antecedent conditions and precipitation, as well as a record of current and antecedent temperatures.

One must not conclude, however, that the work of the Service will be limited to the collection and compilation of the information. On the contrary, it is planned not only to analyze the information resulting from these studies, but to compile and analyze all existing rainfall records and other pertinent data in the various run-off problem areas in such a manner as to make possible the application of the resulting run-off data to the entire problem area. The application of the data will be extended to wider areas by means of records secured from artificial rainfall test plots on other areas to which the run-off data are to be applied.

## Organization and Present Status of the Work.

The run-off studies are conducted by the Divisions of Operations and Research of the Soil Conservation Service.

The studies were planned and the technical phases of the work are directed by the Washington office of the Section of Watershed and Hydrologic Studies. The Section of Engineering of the Division of Operations was the prime mover in getting the work started and is constantly on guard to remove such administrative difficulties as arise from time to time. The regional engineers,

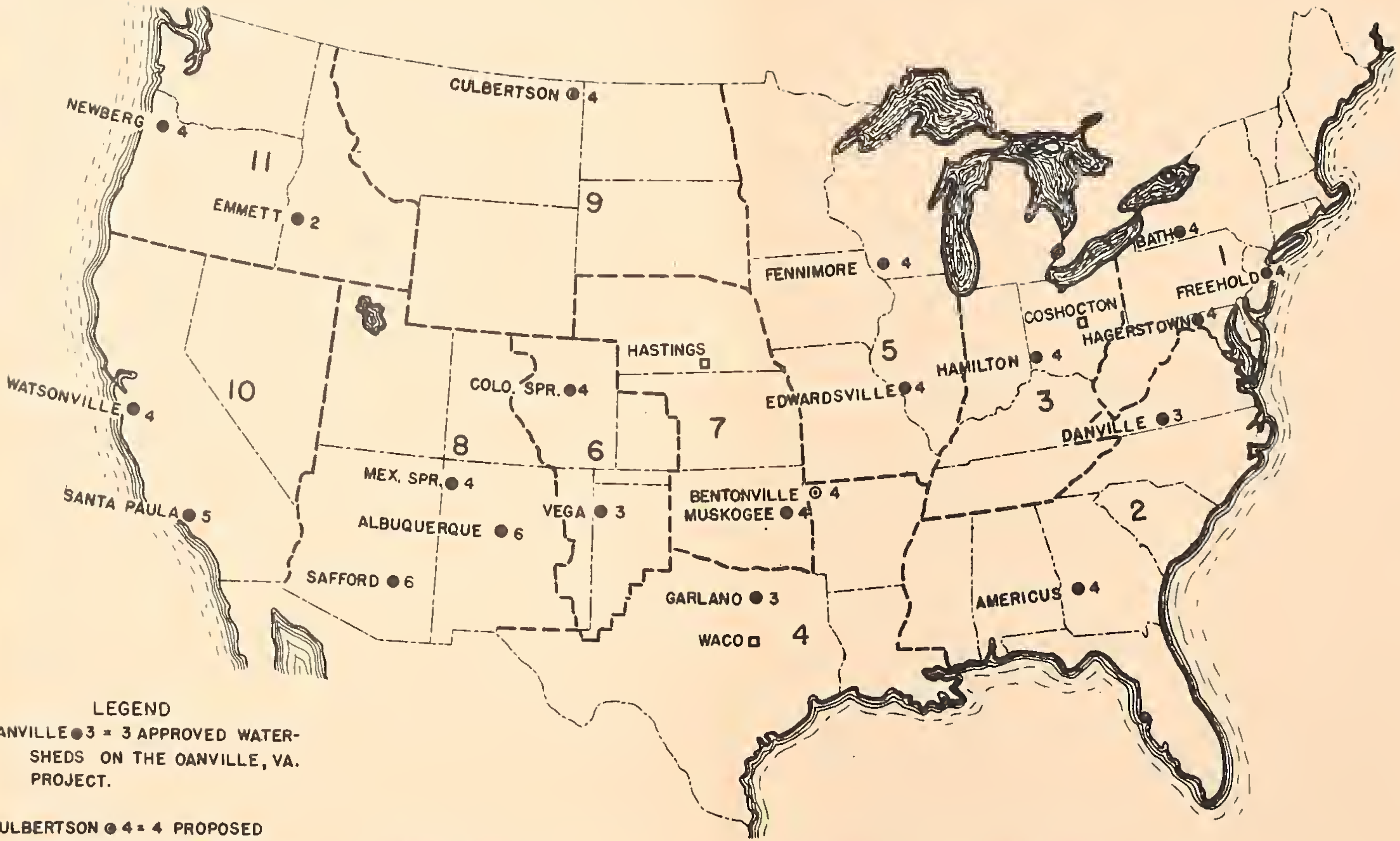
the project managers, and the engineers assigned to these studies on the individual projects have generally shown great interest in this work.

Considerable progress was made within the last year, and it is expected that all the installations on the 21 projects will be completed before July 1, 1938. The location of the run-off studies and the number of drainage basins under investigation on each project as well as the locations of the experimental watersheds, are shown in figure 11.

The characteristics of the drainage basins and the status of construction on April 25, 1938 is shown in table 1. It will be noted from this table that the installations have been completed and records are being obtained from 17 drainage basins on 5 demonstration projects. The work on practically all other projects is actively under way. Table 1 also gives the sizes of the areas, the slope, soils, vegetative cover and the approximate discharge capacity of the weirs.

## CONCLUSION

In conclusion, the writer wishes to point out the great importance of these studies to engineers and students of run-off phenomena. They represent the first opportunity to secure a large amount of information which will be collected and made available in a standard manner. It is estimated that records of about 4,000




LEGEND

DANVILLE ● 3 = 3 APPROVED WATERSHEDS ON THE OANVILLE, VA. PROJECT.

CULBERTSON ● 4 = 4 PROPOSED WATERSHEDS ON THE CULBERTSON, MONT. PROJECT

□ EXPERIMENTAL WATERSHEDS

RUN-OFF STUDIES ON DEMONSTRATION PROJECTS OF THE SOIL CONSERVATION SERVICE

FIGURE-11

TABLE I

RUN-OFF STUDIES ON THE DEMONSTRATION PROJECTS OF THE SOIL CONSERVATION SERVICE
CHARACTERISTICS OF DRAINAGE AREAS AND STATUS OF CONSTRUCTION

April 25, 1938.

(Note: * = Completed installations to date (April 25, 1938)   * = Pasture, Meadow or Range
** Columbus Ogee Control, Current Motor Rating   *** = Compound Weir

| No. | Location: SCS Region | Location: State | Location: Town | Location: Farm Name | Gaging Station No. | Area In Acres | Number Rainfall Stations | Slope: Range | Slope: Aver. | Vegetal Cover (% area): Timber | Vegetal Cover (% area): Grass* | Vegetal Cover (% area): Cultivated | Soil Type: Series | Soil Type: Texture | Measuring Weir: Side Slopes | Measuring Weir: Head | Measuring Weir: Top Width | Measuring Weir: Capacity (cfs): c.f.s. | Measuring Weir: Capacity (cfs): in/hr | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) |
| 1* | 1 | N. Y. | Bath | Switzer Creek | W-1 | 2000.0 | 12 | 0-50 | 15 | 11 | 43 | 36 | Glacial Origin | Mostly well-drained | **C-cm | 6.0 | 50.0 | 3000 | 1.5 | Control to be changed |
| 2* | " | " | " | Gehrig | W-II | 12.5 | 1 | 0-25 | 10 | 0 | 40 | 60 | Bath | Deep sandy loam | 2:1 | 2.6 | 10.4 | 58 | 4.6 | Strip cropped |
| 3* | " | " | " | Coye | W-III | 24.0 | 2 | 0-30 | 15 | 0 | 45 | 55 | Lordstown & Mardin | Shallow loam | 2:1 | 3.3 | 13.2 | 100 | 4.2 | " " |
| 4* | " | " | " | Edmondo | W-IV | 62.5 | 1 | 0-20 | 10 | 2 | 30 | 68 | Fremont | Shallow clay loam | ***2:1 5:1 | 3.5 | 29.0 | 200 | 3.2 | |
| 5* | " | N. J. | Freehold | Surgent | W-I | 21.0 | 1 | 0-15 | 8 | 0 | 5 | 95 | Collington | Loam & sandy loam | ***3:1 5:1 | 2.5 | 21.0 | 65 | 3.1 | Terraced |
| 6* | " | " | " | Smith | W-II | 30.0 | 2 | 1-10 | 5 | 0 | 20 | 80 | Colts Neck | " " " | 2:1 | 3.0 | 12.0 | 80 | 2.7 | |
| 7* | " | " | " | Duval | W-III | 70.0 | 2 | 1-20 | 5 | 0 | 50 | 50 | Collington | Sandy loam | 2:1 | 4.1 | 16.4 | 175 | 2.5 | |
| 8* | " | " | " | Ward | W-IV | 100.0 | 2 | 1-10 | 3 | 0 | 30 | 70 | | " " | 5:1 | 3.3 | 33.0 | 250 | 2.5 | |
| 9* | " | Md. | Hagerstown | Reeder | W-I | 54.0 | 2 | 0-25 | 8 | 0 | 60 | 30 | Frankstown & Hagerstown | Silt loam | 3:1 | 3.4 | 20.4 | 175 | 3.2 | |
| 10 | " | " | " | Stein | W-II | 75.0 | 2 | Information not yet available | | | | | | | | | | | | |
| 11* | " | " | " | Rohrer | W-III | 40.0 | 2 | 3-30 | 10 | 7 | 33 | 60 | Porters | Gravelly loam | ***3:1 10:1 | 2.3 | 39.0 | 140 | 3.5 | |
| 12 | " | " | " | | W-IV | | | Drainage area not yet selected | | | | | | | | | | | | |
| 13 | 2 | Ga. | Americus | Battle, E.A. | W-I | 24.0 | 1 | 0-7 | 3 | 0 | 25 | 75 | Norfolk & Ruston | Sandy loam | 3:1 | 3.0 | 18.0 | 120 | 5.0 | Terraced |
| 14 | " | " | " | Battle, Mrs. A. | W-II | 35.0 | 2 | 0-7 | 3 | 20 | 20 | 60 | Mostly Ruston | " " | 2:1 | 3.7 | 14.8 | 140 | 4.0 | " |
| 15 | " | " | " | " " " | W-III | 30.0 | 1 | 3-7 | 5 | 0 | 0 | 100 | Ruston | Loamy sand | 2:1 | 3.8 | 15.2 | 150 | 5.0 | Terraced |
| 16 | " | " | " | Merrit | W-IV | 52.0 | 2 | 0-3 | 2 | 0 | 0 | 100 | Red Bay | Sandy loam | 2:1 | 4.4 | 17.6 | 212 | 4.0 | |
| 17 | " | Va. | Chatham | Easley | W-I | 12.6 | 1 | 3-20 | 7 | 0 | 80 | 20 | Madison | Fine sandy loam | 2:1 | 3.1 | 12.4 | 85 | 6.75 | Terraced |
| 18 | " | " | " | Bryant | W-II | 27.0 | 1 | 3-12 | 7 | 0 | 0 | 100 | Granville | Sandy loam | Measuring weir not yet designed | | | | | " |
| 19 | " | " | " | Rogers | W-III | 13.0 | 1 | 3-7 | 5 | 0 | 30 | 70 | Appling & Durham | Sandy loam | " " " " | | | | | " |
| 20 | 3 | Ohio | Hamilton | Blake | W-I | 193.0 | 3 | 0-25 | 5 | 10 | 20 | 70 | Russell & Fincastle | Silt loam | 5:1 | 4.9 | 49.0 | 680 | 3.5 | |
| 21 | " | " | " | Dean | W-II | 17.6 | 1 | 3-25 | 10 | 0 | 100 | 0 | Russell | " " | 2:1 | 3.0 | 12.0 | 80 | 4.5 | |
| 22 | " | " | " | Bennett | W-III | 28.6 | 1 | 0-8 | 5 | 0 | 100 | 0 | Russell & Fincastle | " " | 2:1 | 3.7 | 14.8 | 135 | 4.7 | Terraced |
| 23 | " | " | " | Schwab | W-IV | 15.6 | 1 | 5-12 | 8 | 0 | 35 | 65 | " " " | " " | 3:1 | 2.7 | 16.2 | 90 | 5.7 | |
| 24 | 4 | Texas | Garland | Guthrie | W-I | 22.0 | 1 | 0.5-2.5 | 1 | 0 | 30 | 70 | Bell | Clay | 3:1 | 3.0 | 18.0 | 120 | 5.4 | Terraced |
| 25 | " | " | " | White | W-II | 94.0 | 2 | 1-4 | 2 | 0 | 10 | 90 | Bell & Boneton | " | 5:1 | 4.5 | 45.0 | 564 | 6.0 | " |
| 26 | " | " | " | Oates | W-III | 10.5 | 1 | 2-6 | 3.5 | 0 | 90 | 10 | Houston | Black clay | 3:1 | 2.5 | 15.0 | 74 | 7.0 | |
| 27 | " | Ark. | Bentonville | Beard | W-I | 12.0 | 1 | 0-5 | 3 | 0 | 0 | 100 | Baxter, Centerton, Newtonia | Silt loam, gravelly silt loam | 2:1 | 3.0 | 12.0 | 86 | 7.2 | Project not yet approved |
| 28 | " | " | " | Henderson | W-II | 12.0 | 1 | 0-14 | 8 | 0 | 100 | 0 | Baxter | Gravelly & stony silt loam | 2:1 | 3.0 | 12.0 | 86 | 7.2 | " " " " |
| 29 | " | " | " | " | W-III | 17.0 | 1 | 0-5 | 3 | 0 | 100 | 0 | Centerton, Baxter | Silt loam, gravelly silt loam | 2:1 | 3.0 | 12.0 | 86 | 5.1 | " " " " |
| 30 | " | " | " | Blair | W-IV | 22.0 | 1 | 2-14 | 8 | 100 | 0 | 0 | Clarksville, Baxter | Gravelly silt loam | 2:1 | 3.4 | 13.6 | 110 | 5.0 | " " " " |
| 31* | 5 | Ill. | Edwardsville | Love | W-I | 28.0 | 1 | 0-10 | 8 | 0 | 100 | 100 | Alma & Bogota | Silt loam | 2:1 | 3.5 | 14.0 | 120 | 4.3 | |
| 32* | " | " | " | " | W-II | 50.4 | 2 | 5-30 | 15 | 0 | 54 | 46 | Alma, Bogota & Elco | " " | 3:1 | 3.7 | 22.2 | 205 | 4.1 | |
| 33* | " | " | " | Buchta | W-III | 13.2 | 1 | 3-14 | 5 | 0 | 50 | 50 | Alma & Bogota | " " | 2:1 | 2.5 | 10.4 | 50 | 3.8 | Terraced |
| 34* | " | " | " | Love | W-IV | 282.0 | 7 | 0-30 | 10 | 10 | 40 | 50 | Alma, Bogota & Elco | " " | 5:1 | 4.6 | 46.0 | 590 | 2.1 | |
| 35 | " | Wis. | Fennimore | Borton | W-I | 320.0 | 9 | 3-15 | 8 | 0 | 15 | 85 | Tama, Dubuque & Clinton | " " | 5:1 | 5.25 | 52.5 | 800 | 2.5 | |
| 36 | " | " | " | Ruchti | W-II | 57.5 | 1 | 3-12 | 7 | 0 | 15 | 85 | Tama & Dubuque | " " | Not yet designed, another area may be substituted | | | | | |
| 37 | " | " | " | Horton | W-III | 54.3 | 2 | 5-15 | 10 | 0 | 15 | 85 | Tama & Dubuque | " " | 3:1 | 3.75 | 22.5 | 212 | 3.9 | |
| 38 | " | " | " | Borton | W-IV | 170.0 | 4 | 3-15 | 8 | 0 | 15 | 85 | Dubuque & Clinton | " " | 5:1 | 4.6 | 46.0 | 590 | 3.5 | |
| 39* | 6 | Texas | Vega | Bauer | W-I | 143.0 | 2 | 0-3 | 1.5 | 0 | 35 | 65 | Pullman, Spur & Potter | Silty clay & clay loam | 5:1 | 4.6 | 46.0 | 590 | 4.1 | |
| 40* | " | " | " | Landergin | W-II | 112.1 | 2 | 0-3 | 1.5 | 0 | 100 | 0 | " " " " | " " " " " | 5:1 | 4.1 | 41.0 | 440 | 3.9 | |
| 41* | " | " | " | Langham | W-III | 23.6 | 2 | 8-50 | 25 | 0 | 100 | 0 | Rough broken land | Gravelly & colluvial loamy sand | 3:1 | 3.2 | 19.2 | 130 | 5.5 | |
| 42 | " | Colo. | Colo. Spgs. | Fulsom | W-I | 10.2 | 1 | 3-8 | 4 | 0 | 0 | 100 | Sandy loam top soil, clay loam subsoil | | 2:1 | 2.6 | 10.4 | 57 | 5.6 | |
| 43 | " | " | " " | " | W-II | 41.2 | 2 | 1-10 | 5 | 0 | 100 | 0 | Derived from Dawson sandstone, friable loamy sand | | 3:1 | 3.7 | 22.2 | 205 | 5.0 | |
| 44 | " | " | " " | Slaney | W-III | 32.8 | 1 | 2-8 | 6 | 0 | 100 | 0 | Sandy loam top soil, clay loam subsoil | | 3:1 | 3.4 | 20.4 | 165 | 5.0 | |
| 45 | " | " | " " | Ayer | W-IV | 36.2 | 2 | | | 0 | 100 | 0 | Gravelly sandy loam, light-textured subsoil | | 3:1 | 3.5 | 21.6 | 190 | 5.3 | |
| 46 | 7 | Okla. | Muskogee | Morris Estate | W-I | 91.0 | 2 | 3-11 | 5 | 0 | 0 | 100 | Spearfish, Bates | Fine sandy loam | 5:1 | 4.1 | 41 | 440 | 4.8 | Level terraces |
| 47 | " | " | " | Stone | W-II | 67.0 | 2 | 2-11 | 6 | 0 | 0 | 100 | Parsons, Bates | " " " | 5:1 | 3.7 | 37 | 340 | 5.0 | Terraced |
| 48 | " | " | " | Reed | W-III | 26.0 | 1 | 3-7 | 5 | 0 | 0 | 100 | Spearfish, Bates | Fine sandy, sandy clay loams | 3:1 | 3.1 | 18.6 | 132 | 5.1 | Other areas may be substituted |
| 49 | " | " | " | Trumbo | W-IV | 25.0 | 1 | 3-15 | 10 | 0 | 100 | 0 | Bates | Fine sandy & stony loam | 3:1 | 3.0 | 18 | 118 | 4.75 | for W-I and W-II |
| 50 | 8 | Ariz. | Safford | Public Domain | W-I | 520.0 | 3 | 0-25 | 15 | 0 | 100 | 0 | Basalt Origin | Stone & gravel with clay | 5:1 | 5.0 | 50.0 | 720 | 1.4 | |
| 51 | " | " | " | State (leased) | W-II | 1030.0 | | 0-25 | 10 | 0 | 100 | 0 | " " | Stony, gravelly sandy loam | Not yet designed | | | | | |
| 52 | " | " | " | " " | W-III | 380.0 | | 5-25 | 20 | 0 | 100 | 0 | Granite Origin | " " " " | " " " | | | | | |
| 53 | " | " | " | Public Domain | W-IV | 780.0 | | 0-10 | 5 | 0 | 100 | 0 | Calcareous | Gravelly & sandy loam | " " " | | | | | |
| 54 | " | " | " | State (leased) | W-V | 730.0 | 5 | 10-25 | 15 | 0 | 100 | 0 | Granite Origin | Stony & sandy loam | 5:1 | 5 | 50 | 730 | 1.0 | |
| 55 | " | " | " | " " | W-VI | 500.0 | 4 | 5-25 | 12 | 0 | 100 | 0 | Calcareous | Gravelly & sandy loam | 5:1 | 4.6 | 46 | 590 | 1.2 | |
| 56 | " | N. M. | Mexican Sp. | Parshall Wash | W-I | 367.0 | | 5-50 | 30 | 0 | 100 | 0 | | Exposed rock silty bottom lands | Not yet designed, drainage areas will be reduced | | | | | |
| 57 | " | " | " " | Hororose Wash | W-II | 1700.0 | | 0-50 | 14 | 0 | 100 | 0 | | Clay bad lands | " " " " " " " " | | | | | |
| 58 | " | " | " " | Deer Springs | W-III | 3025.0 | | 0-50 | 16 | 0 | 100 | 0 | | Broken rock silty bottom lands | " " " " " " " " | | | | | |
| 59 | " | " | " " | Muddy Creek | W-IV | 3760.0 | | 0-50 | 20 | 0 | 100 | 0 | | Bad lands | " " " " " " " " | | | | | |
| 60 | " | N. M. | Albuquerque | Caña Del Rio | W-I | 140.0 | | 2-20 | 5 | 0 | 100 | 0 | Basalt Tertiary Flows | | Project approved, designs not completed yet | | | | | |
| 61 | " | " | " | " " " | W-II | 770.0 | | 2-40 | 10 | 0 | 100 | 0 | " " " | | " " " " " " | | | | | |
| 62 | " | " | " | " " " | W-III | 62.0 | | 5-50 | 20 | 100 | 0 | 0 | Santa Fe formation sand, gravels & clay | | " " " " " " | | | | | |
| 63 | " | " | " | S. Montano | W-IV | 202.0 | | 2-100 | 25 | 50 | 50 | 0 | Mesas and bluffs | | " " " " " " | | | | | |
| 64 | " | " | " | — | W-V | 44.0 | | 5-30 | 20 | 0 | 100 | 0 | Soft sandy shales Mesa Verde formation | | " " " " " " | | | | | |
| 65 | " | " | " | — | W-VI | 186.0 | | 5-30 | 15 | 0 | 100 | 0 | " " " " " " | | " " " " " " | | | | | |
| 66 | 9 | Mont. | Culbertson | Jenson | W-I | 700.0 | | (Project not approved yet, detailed information not available) | | | | | | | | | | | | |
| 67 | " | " | " | " | W-II | 1500.0 | | " " " " " " " " " | | | | | | | | | | | | |
| 68 | " | " | " | " | W-III | 120.0 | | " " " " " " " " " | | | | | | | | | | | | |
| 69 | " | " | " | — | W-IV | 48.0 | | " " " " " " " " " | | | | | | | | | | | | |
| 70 | 10 | Calif. | Santa Paula | Polerino | W-I | 350.0 | 4 | 25-40 | 30 | 0 | 85 | 15 | Altamont | Loam and clay loam | 2:1 | 7.5 | 30.0 | 800 | 2.3 | |
| 71 | " | " | " " | Genoveseio | W-II | 130.0 | 2 | 25-40 | 30 | 0 | 80 | 20 | " | Stony loam | 2:1 | 5.5 | 22.0 | 370 | 2.8 | |
| 72 | " | " | " " | Legomarsino | W-III | 42.0 | 2 | 4-40 | 18 | 0 | 0 | 100 | Altamont & Ledgewood | Loam | 2:1 | 3.6 | 14.4 | 130 | 3.0 | |
| 73 | " | " | " " | Genoveseio | W-IV | 43.0 | 2 | 4-40 | 25 | 0 | 0 | 100 | Altamont Huerhuero | Loam | 2:1 | 3.6 | 14.4 | 130 | 3.0 | |
| 74 | " | " | " " | Davis | W-V | 90.0 | 2 | 11-25 | 15 | 0 | 0 | 100 | Rincon | Sandy loam, clay loam | 3:1 | 4.0 | 24.0 | 250 | 2.8 | |
| 75 | " | " | Watsonville | Travers | W-I | 14.5 | 1 | 10-25 | 15 | 0 | 0 | 100 | Tierra & Montezuma | Silty clay, clay loam & loam | 2:1 | 3.0 | 12.0 | 88 | 6.0 | Orchard |
| 76 | " | " | " | Kuselich | W-II | 18.3 | 1 | 10-40 | 20 | 0 | 20 | 80 | Moro Cojo | Deep sandy loam | Not yet designed | | | | | Orchard |
| 77 | " | " | " | Zille | W-III | 39.8 | 2 | 10-25 | 12 | 0 | 0 | 100 | Elkhorn | Sandy loam | " " " | | | | | To be terraced |
| 78 | " | " | " | Riedon | W-IV | 32.3 | 2 | 4-40 | 30 | 0 | 100 | 0 | McClusky Tierra | Clay loam | " " " | | | | | |
| 79 | 11 | Ore. | Newberg | Grosse | W-I | 13.5 | 1 | 3-15 | 10 | 0 | 0 | 100 | Olympic | " " | 2:1 | 2.2 | 8.8 | 37 | 2.7 | Walnut orchard with cover crops |
| 80 | " | " | " | Nelson | W-II | 12.7 | 1 | 20-40 | 30 | 100 | 0 | 0 | Melbourne | Loam | 2:1 | 1.8 | 7.2 | 23 | 1.8 | |
| 81 | " | " | " | Frankhauser | W-III | 13.0 | 1 | 5-18 | 12 | 0 | 0 | 100 | " | " | 2:1 | 2.2 | 8.8 | 37 | 2.8 | Terraced orchard |
| 82 | " | " | " | Lyons | W-IV | 7.0 | 1 | 5-15 | 10 | 0 | 0 | 100 | " | " | 2:1 | 1.65 | 6.6 | 18 | 2.6 | Orchard with or without cover crop |
| 83 | " | Idaho | Emmett | Gardner | W-I | 240.0 | 3 | 15-30 | 20 | 0 | 100 | 0 | Basaltic | Rocky | 2:1 | 4.5 | 18.0 | 225 | 0.94 | |
| 84 | " | " | " | Seekman | W-II | 70.0 | 2 | 20-35 | 25 | 0 | 92 | 8 | Granitic | — | 2:1 | 3.6 | 14.4 | 130 | 1.86 | |

to 6,000 run-off-producing rains will be obtained each year from all of these studies. If the work is conducted as outlined for a number of years, it will result in an unequalled contribution to the science of hydrology and to the engineering and other professions, and will undoubtedly result in the saving of vast amounts of public and private funds.

It is gratifying to know of the great interest in these studies shown by many technicians and administrative officers of the Service and especially by practicing engineers and hydrologists outside of the Service. That the collected data are urgently needed and are extremely useful can be shown by an interesting incident. The writer completed the installation of the recorders at the Edwardsville, Ill., project on March 12. Between March 15 and April 15 several significant rains occurred. The resulting records proved so important in connection with a large project now under consideration in the vicinity of St. Louis that the consulting engineer (an eminent hydrologist) sent members of his staff to Edwardsville to copy the records. This hydrologist recently told the writer that the Edwardsville records will be of great value to engineers and public agencies engaged in the planning and construction of hydraulic structures and projects in the Middle West. The value of the records to the Soil Conservation Service is, of course, obvious.

LITERATURE CITED

(1) GUGLIELMINI (1658-1710)

"La Misura Dell'acque Coerenti."

(2) D. S. MYER

"Soil Conservation Districts" AGRICULTURAL ENGINEERING, March 1938.

(3) T. A. MUNSON

"Formulas and Methods in General Use by Engineers to Determine Runoff from Watershed Areas", May 1933, THE TEXAS ENGINEER, April 1934, pages 7 - 23.

(4) C. S. JARVIS AND OTHERS

"Floods in the United States" U.S. GEOLOGICAL SURVEY WATER SUPPLY PAPER 771, pages 32 and 62.

(5) C. E. RAMSER

"Run-off from Small Agricultural Areas" JOURNAL OF AGRICULTURAL ENGINEERING, Vol. 34, No. 9, May 1927, pages 797-823.

(6) G. W. MUSGRAVE AND R. A. NORTON

"Soil and Water Conservation Investigations", SOIL CONSERVATION EXPERIMENT STATION, CLARINDA, IOWA, PROGRESS REPORT, 1931-35, Tech. Bull. No. 558, February 1937.

(7) P. C. McGREW AND G. M. HORNER

"Soil and Water Conservation Investigations", PROGRESS REPORT, 1931-35, PACIFIC NORTHWEST SOIL CONSERVATION EXPERIMENT STATION, Pullman, Washington, SCS-ESR-2, April 1937.

(8) M. O. HILL, H. M. ELWELL AND J. W. SLOSSER

"Soil and Water Conservation Investigations", PROGRESS REPORT, 1930-35, RED PLAINS SOIL CONSERVATION EXPERIMENT STATION, Guthrie, Oklahoma, SCS-ESR-3, July 1937.

(9) O. E. HAYS AND V. J. PALMER

"Soil and Water Conservation Investigations", PROGRESS REPORT, 1932-35, UPPER MISSISSIPPI VALLEY SOIL AND WATER CONSERVATION EXPERIMENT STATION, La Crosse, Wisconsin, SCS-ESR-1, September 1937.

(10) H. O. HILL, S. J. MECH AND J. B. POPE

"Soil and Water Conservation Investigations", PROGRESS REPORT, 1931-36, ARKANSAS-LOUISIANA-EAST TEXAS LANDS SOIL AND WATER CONSERVATION EXPERIMENT STATION, Tyler, Texas, SCS-ESR-4, January 1938.

(11) F. T. MAVIS AND EDWARD SONCEK

"A Summary of Hydrologic Data", RALSTON CREEK WATERSHED, 1924-1935, UNIVERSITY OF IOWA STUDIES IN ENGINEERING, Bull. 9, December 1936.

(12) C. G. BATES AND A. S. HENRY

"Forest and Stream-Flow Experiment at Wagon Wheel Gap, Colorado" (final report), MONTHLY WEATHER REVIEW SUPPLEMENT 30, 1928.

(13) A. W. SAMPSON AND L. H. WEYL

"Range Preservation and Its Relation to Erosion Control on Western Grazing Lands", U.S.D.A. Bull. 675.

(14) METCALF AND EDDY

"American Sewerage Practice", Vol. 1, 2nd Ed., 1928, pages 278-319.

(15) M. M. BERNARD

Discussion of "Flood Flow Characteristics" by C. S. Jarvis, TRANS. AMER. SOC. OF CIV. ENG., Vol. 89, 1926, page 1087.

(16) E. P. ARNESON

"Rational Runoff Theory Applied to Design of Road Ditches and Channel Changes" THE TEXAS ENGINEER, July 1932, pages 7 - 20.

(17) R. E. HORTON

"Hydrologic Interrelations of Water and Soils", November 1936, PROC. SOIL SC. SOC. OF AMERICA, Vol. 1, pages 401-429.

(18) C. E. RAMSER

"Brief Instructions on Methods of Gully Control", August 1933.

(19) C. E. RAMSER AND D. B. KRIMGOLD

"General Working Plan for the North Appalachian Experimental Watershed", November 1935.

(20) C. E. RAMSER

"Hydrologic Investigations on Selected Watersheds", SOIL CONSERVATION, February 1938.